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THE PHOSPHORUS BALANCE OF RAINBOW TROUT

By Paivi Eskelinen
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Central Fish Farm of Laukaa

In S. Salonen (ed.): Reduction of the Pollution Effects of Fish Farming on Water Systems. Collected Papers from the Water Research Day, 13 October 1983, University of Kuopio.

Phosphorus balance tests were carried out on third-summer rainbow trout in four test tanks in the Central Fish Farm of Laukaa during the summer of 1983. The objective was to examine the phosphorus balance of four different types of feed and the distribution of the feed phosphorus among the fish reared, the water outflow and the excrement sludge collecting on the bottom of the tank. Another objective was to develop a material-balance testing tank that would be as adaptable as possible and lend itself to the testing of different variables in material-balance studies as well as to uses such as nutrition studies. 33*

*Numbers in the right-hand margin indicate the corresponding page numbers in the original. Translator's note.

TEST ARRANGEMENTS

Four fibre-glass test tanks with a cone-shaped bottom and with a water capacity of 230 L were used in the material-balance tests (Fig. 1). The cone-shaped part was separated from the upper part by a wire mesh and there was a plastic hose in the bottom of the cone for sludge removal.

The water entered and left the tanks at the surface and it was guided into a circular motion in the tanks. Two test periods of ten days were carried out during the summer, i.e. June 14-23 and July 19-28, with the temperature of the water varying between 13.4°C and 14.6°C during Test Period I and between 15.2°C and 17.3°C during Test Period II (Fig. 2).

The fish were third-summer rainbow trout and the fish density of the tanks was about 7 kg/tank. The fish were weighed separately in the beginning and at the end of the test with a precision of 0.1 g. Four different brands of rainbow trout feed were used in the test, all of the same or comparable pellet size (8-9.5 mm). The fish were fed by hand at a 1.2% feeding efficiency twice a day during Test Period I, and the quantity of feed used and wasted was monitored carefully.

SAMPLING AND ANALYSIS

A composite sample was taken from the water inflow and outflow daily. The total phosphorus, solid matter and oxygen contents were analyzed in the water samples, and the temperature of the inflow was measured.

The sludge that settled on the bottoms of the tanks was removed twice a day before feeding. The volume of the settled sludge was measured and the dry weight determined. The phosphorus content and ignition residue of the combined sample of one day were determined.

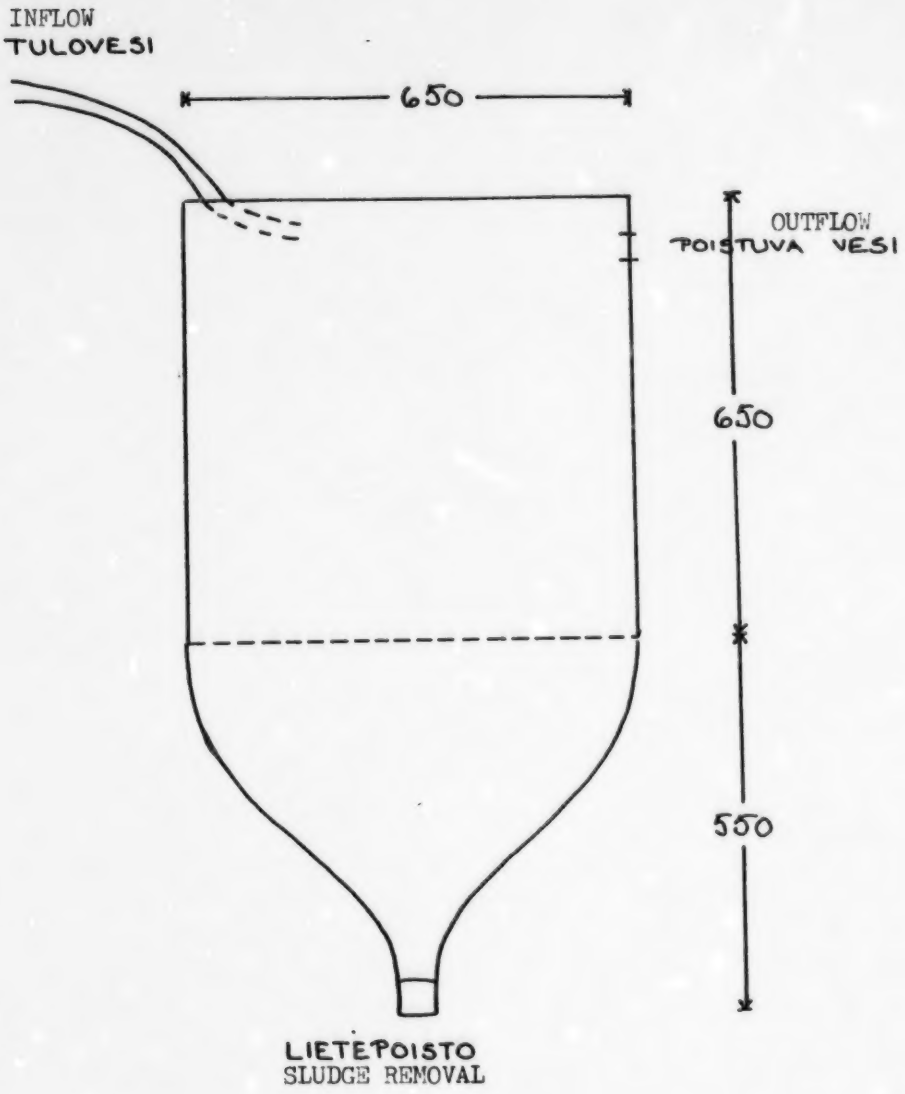
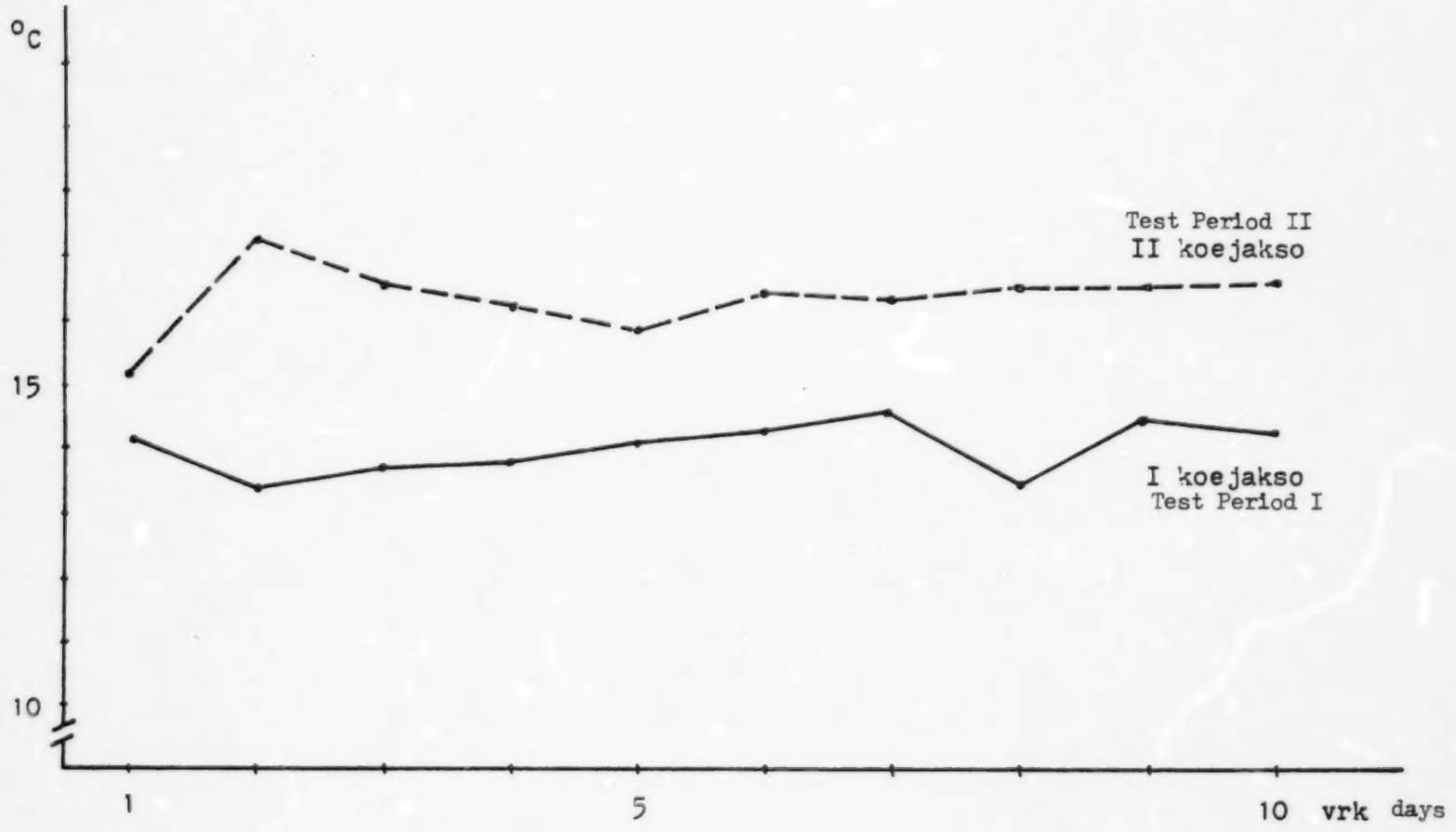


Figure 1.
Kuva 1. Ainetasekoeallas
Material balance test tank



Kuva 2. Koealtaisiin tulevan veden lämpötila °C.
Figure 2. Temperature of water flowing into test tanks in °C.

The volume, solid matter and total phosphorus of the sludge water, 36
i.e. the water separating on top of the waste during sedimentation, were determined on the basis of the composite sample. A 0.375% phosphorus content (fresh weight), analyzed by the VTT (National Technological Research Institute) Food Laboratory in whole rainbow trout (average weight 650 g) in 1982 served as the phosphorus content of the fish. Uneaten feed was removed from the bottoms of the tanks after feeding, dried and weighed to determine the actual feed consumption.

RESULTS

Growth and feed consumption of the fish

The predicted growth rate of the fish was 0.86%/day during Test Period I and 1.00%/day during Test Period II. During Test Period II, the growth rate was, with the exception of Tank No. 2, about one half of this, whereby the feed conversion factors and amounts of waste feed (Table 1) also jumped. The chosen feeding intensity of Test Period II was maybe too high, particularly because the oxygen content of the water inflow of the facility was at the end of July at its lowest before supplementary oxygenation was installed. Even if the oxygen saturation of the outflow of the test tanks was 70% on the average, it is possible that a tank had pockets of reduced oxygen.

Amounts of sludge

The amounts of sludge calculated both as fresh sludge and as dry sludge vary considerably in different brands of feed. Table 2 presents the 37
amounts of fresh sludge and Table 3 the amounts of dry sludge per day, kg of feed given and growth of the fish. The amount of sludge was greatest for feed No. 3 during both test periods - about twice that of

the other feeds as dry matter per kg of feed. A high feed conversion factor may also cause the daily amounts of sludge to grow, but there is no clear interdependency.

Table 1. Growth of the fish, feed conversion factors and uneaten feed in percentage of feed given.

Taulukko 1. Kalojen kasvu, rehukertoimet ja syömättä jääneen rehun määrä prosentteina syötetystä rehusta

	Kasvu g Growth	%/vrk /day	Rehu-kerroin Feed conversion factor	Hukka-rehu % Feed waste
I KOEJAKSO TEST PERIOD I				
1	532	0.73	1.54	1.53
2	473	0.63	1.81	0.27
3	385	0.54	2.11	1.99
4	665	0.89	1.27	1.10
II KOEJAKSO TEST PERIOD II				
1	360	0.54	2.38	7.64
2	760	1.02	1.19	6.06
3	379	0.53	2.30	11.08
4	427	0.58	2.28	2.65

Table 2. Amounts of fresh sludge collected from the tanks per day, kg of feed given and growth of the fish.

Taulukko 2. Altaista kerätyt tuorelietemäärät vuorokautta, syötettyä rehukiloa ja kalojen lisäkasvua kohti

	Liete l/vrk Sludge, L/day	Liete l/ rehunkulutus kg Sludge/feed consumption, L/kg	Liete l/ kalojen kasvu kg Sludge/growth of fish, L/kg
I KOEJAKSO TEST PERIOD I			
1	0.182	2.20	3.41
2	0.176	2.05	3.71
3	0.207	2.55	5.39
4	0.198	2.35	2.98
II KOEJAKSO TEST PERIOD II			
1	0.192	2.23	5.32
2	0.152	1.68	2.00
3	0.216	2.48	5.71
4	0.229	2.35	5.35

Table 3. The amounts of dry sludge in the tanks per day, feed consumption and growth of the fish.

Taulukko 3. Altaiden kuivalietemäärät vuorokautta, rehunkulutusta ja kalojen lisäkasvua kohti

	Liete g/vrk Sludge, g/day	Liete kg/ rehunkulutus kg Sludge/feed consumption, kg/kg	Liete kg/ kalojen kasvu kg Sludge/growth of fish, kg/kg
I KOEJAKSO TEST PERIOD I			
1	12.27	0.149	0.231
2	11.53	0.135	0.244
3	20.88	0.257	0.543
4	10.94	0.130	0.164

II KOEJAKSO TEST PERIOD II			
1	11.52	0.134	0.320
2	9.78	0.108	0.129
3	18.74	0.215	0.494
4	12.11	0.124	0.284

Feed characteristics

Table 4. The phosphorus contents and moisture percentages of the production lots of feeds studied in this test.

Taulukko 4. Tutkittujen rehujen tässä kokeessa olleiden valmistuserien fosforipitoisuudet ja kosteusprosentit.

Rehu Feed	1	2	3	4
Fosforipitoisuus % Phosphorus content %	0.89	1.20	0.86	0.96
Kosteus % Moisture %	10.1	7.9	10.6	9.6

Table 5. Fat, protein and ash contents indicated in manufacturers' guarantees for the feed types tested.

Taulukko 5. Valmistajien vakuustodistuksissa rasva-, valkuais- ja tuhkapitoisuudet kokeiden rehutyypeille.

	Rehu Feed	1	2	3	4
Crude fat	Raakarasva %	15.0	17.5	18.0	18.0
Crude protein	Raakavalkuainen %	37.5	50.0	40.0	51.0
Ash	Tuhka %	6.5	9.0	5.5	11.0

Phosphorus balance

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The 10-day phosphorus balance of each type of feed (Tables 6 a and 6 b) is calculated so that the amount of phosphorus entering the system equals the phosphorus entering in the feed and the water inflow. The tank retains any phosphorus bound during the growth of the fish

and loses any phosphorus bound with the outflow and the sludge. The phosphorus of the inflow is subtracted from the contents of the outflow.

The percentage of the feed phosphorus that binds with the fish is small, only about 30% at its maximum. The percentage of the feed phosphorus binding with the fish fluctuated between 14 and 33% in American studies on the phosphorus balance of rainbow trout. This percentage fluctuated between types of feed, but the feed appears to have extra phosphorus or the phosphorus of the feed cannot be used by the fish. Different nutrition studies have calculated the phosphorus needs of rainbow trout as 0.7 to 0.8%, even up to 1% of the feed (Nose & Arai 1979, Ogino & Takeda 1978) depending primarily on the age of the fish, the quantity of other minerals such as calcium, and the source of the phosphorus.

We know that it is difficult for fish to use the phosphorus of many plant raw materials and organic phosphorus forms in general (Ogino et al. 1979). 39

Tables 7 a and b show the distribution of phosphorus calculated according to the feed given and the mass of fish produced. The potential polluting phosphorus, which does not bind with the fish, divides about equally between the sludge and the water outflow in all types of feed, as earlier material-balance studies have also noted (Selanne et al. 1983, Sumari et al 1982). In this study, the total phosphorus pollution, if the sludge was not removed at all and all the phosphorus bound with the sludge contributed to water pollution, would vary between 5.8 and 10.7 g of phosphorus per kg of feed given. With a full removal of the sludge, the pollution would be 3.0 to 4.7 g of phosphorus per kg of feed. 42

Taulukko 6 a. I koejakson fosforiainetase
Table 6 a. Phosphorus balance of Test Period I.

Rehu Feed	1	2	3	4
1. Rehun fosfori mg (%)	7334 (100)	10284 (100)	6967 (100)	8066 (100)
2. Kalaan sitoutuva fosfori mg (%)	1996 (27)	1775 (17)	1444 (21)	2495 (31)
3. Poistoveden fosfori mg (%)	3530 (48)	4018 (39)	2798 (40)	2551 (32)
4. Lietteen fosfori mg (%)	2925 (40)	4095 (40)	3302 (47)	2225 (28)
5. Laskeutusveden fosfori mg (%)	137 (2)	162 (2)	199 (3)	163 (2)
6. Selvittämätön osuus (%)	(+17)	(-2)	(+11)	(-7)

1) Feed phosphorus mg (%). 2) Phosphorus binding with the fish mg (%).
3) Phosphorus in the outflow mg (%). 4) Sludge phosphorus mg (%).
5) Phosphorus in the sedimentation water mg (%). 6) Unknown (%).

Taulukko 6 b. II koejakson fosforiainetase
Table 6 b. Phosphorus balance of Test Period II.

	1	2	3	4
1. Rehun fosfori mg (%)	7636 (100)	10824 (100)	7501 (100)	9345 (100)
2. Kalaan sitoutuva fosfori mg (%)	1352 (18)	2852 (26)	1422 (19)	1602 (17)
3. Poistoveden fosfori mg (%)	3115 (41)	2915 (27)	2594 (35)	3165 (34)
4. Lietteen fosfori mg (%)	2581 (34)	3791 (35)	3048 (41)	2632 (28)
5. Laskeutusveden fosfori mg (%)	195 (3)	165 (3)	226 (2)	188 (2)
6. Selvittämätön osuus %	(-4)	(-10)	(-2)	(-19)

1) Feed phosphorus mg (%). 2) Phosphorus binding with the fish mg (%).
3) Phosphorus in the outflow mg (%). 4) Sludge phosphorus mg (%).
5) Phosphorus in the sedimentation water mg (%). 6) Unknown (%).

Taulukko 7 a. Fosforin jakautuminen kalaan, lietteeseen ja poistoveteen rehunkulutusta ja kalojen kasvua kohti laskettuna ensimmäisen koejakson aikana (Liete sisältää laskeutusveden)

Feed Rehu	Feed conversion factor Rehu-kerroin	Feed P Rehun P g/kg	Distribution of phosphorus per kg of feed given Fosforin jakautuminen syötettyä rehukiloa kohti Fish Kala g	Sludge Liete g	Water Vesi g	Error Virhe g
1.	1.54	8.9	2.4	3.7	4.3	+ 1.5
2.	1.81	12.0	2.1	5.0	4.7	- 0.2
3.	2.11	8.6	1.8	4.3	3.4	+ 0.9
4.	1.27	9.6	2.9	2.8	3.0	- 0.9

	Feed Rehu g	Distribution of phosphorus per kg of fish produced Fosforin jakautuminen tuotettua kalakiloa kohti Fish Kala g	Sludge Liete g	Water Vesi g	Error Virhe g
1.	13.8	3.8	5.8	6.6	+ 2.4
2.	21.7	3.8	9.0	8.5	- 0.4
3.	18.1	3.8	9.1	7.3	+ 2.1
4.	12.1	3.8	3.6	3.8	- 0.9

Table 7 a. Distribution of phosphorus among the fish, the sludge and the outflow calculated on the basis of feed consumption and growth of fish during Test Period I (sludge includes sedimentation water)

Taulukko 7 b. Fosforin jakautuminen kalaan, lietteeseen ja poistoveteen rehunkulutusta ja kalojen kasvua kohti laskettuna toisen koejakson aikana

Distribution of phosphorus per kg of feed given

Fosforin jakautuminen syötettyä rehukiloa kohti

Feed Rehu	Feed conversion factor Rehu-kerroin	Feed P Rehun P g/kg	Fish Kala g	Sludge Liete g	Water Vesi g	Error Virhe g
1.	2.38	8.9	1.6	3.2	3.6	- 0.5
2.	1.19	12.0	3.2	4.3	3.2	- 1.3
3.	2.30	8.6	1.6	3.5	3.0	- 0.5
4.	2.28	9.6	1.6	2.7	3.3	- 2.0

Distribution of phosphorus per kg of fish produced

Fosforin jakautuminen tuotettua kalakiloa kohti

	Feed Rehu g	Fish Kala g	Sludge Liete g	Water Vesi g	Error Virhe g
1.	21.2	3.8	7.7	8.7	- 1.0
2.	14.2	3.8	5.1	3.8	- 1.5
3.	19.8	3.8	8.0	6.8	- 1.2
4.	21.9	3.8	6.2	7.4	- 4.5

Table 7 b. Distribution of phosphorus among the fish, the sludge and the outflow calculated on the basis of feed consumption and growth of fish during Test Period II

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